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# HEC-2 Water Surface Profiles Program



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# HEC-2 Water Surface Profiles Program

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## Abstract

The Hydrologic Engineering Center (HEC) has been developing generalized computer programs since 1964. The first HEC-2 Water Surface Profiles program was released in 1969. The program was developed by Bill S. Eichert, based on his earlier program Backwater Computations - Any Cross Section. The capabilities of HEC-2, and other HEC programs, have evolved; primarily driven by project and application needs. This incremental program development has continued up to the 1990 release of HEC-2 with Federal Highway culvert capability. While incremental program development will continue at a modest pace, HEC has also embarked on an effort to design and develop the next generation of programs. The current HEC-2 package and the next generation goals are presented.


## Basic Capability

The program was developed to compute steady, gradually-varied flow profiles based on the Standard-step procedure (USACE, 1959). The program can compute one to fifteen water surface profiles for either subcritical or supercritical flow regime. Tributary profiles can also be computed, based on computed main-stem water surface elevation. Either SI or Foot-pound data units can be used. The program remains batch processing, with fixed-format input and output files. PC utilities have been developed to provide interactive graphical and tabular output (Bonner, 1990a).

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## Profile Calculations

Starting water-surface elevation can be based on a given water surface elevation, rating curve, estimated energy slope, or critical depth.

Cross sections are defined in X-Y coordinates, and are separated by three reach lengths for the left and right overbanks, and channel flow paths. A cross section can be repeated, can be vertically adjusted by an incremental elevation change, and horizontally adjusted by a constant ratio. Options can be used to limit the effective flow area in the cross section.

Manning's "n" values can be defined for three flow elements, or "n" can vary by stationing across the section, or vary with depth in the channel. Alternatively, relative roughness coefficients "k" can be defined. Given "k", the program will compute an equivalent "n" value based on the hydraulic radius for the water surface elevation (HEC,1990a, Eq 14).

Average friction slope is estimated using the Average Conveyance for the two sections in a step. Optionally, Average Friction Slope, Geometric Mean Friction Slope, or Harmonic Mean Friction Slope can be used. The program also has a program-determined averaging option that is based on the "profile type" (HEC, 1990a, p 22). Friction loss is computed using a flow-weighted reach length times the average friction slope. Additionally, form losses are computed based on the change in velocity head, if optional Contraction and Expansion Coefficients are defined.

Composite "n" values are computed for the channel (Chow, 1959, Eq 6-17) when the "n" value in the channel changes horizontally and the equivalent side slope of the channel subsection is steeper the 5H to 1V (Davidian, 1984, p 21). Optional input can change the slope criterion, or over-ride the program feature.

Input requirements were modified to eliminate mandatory three title records for each profile and blank records to end the run. Blank lines can be in the input file and "*" Remark records can be used to annotate the input file.

Output for flow distribution was modified to include average depth in each overbank element, as shown below:

```
FLOW DISTRIBUTION FOR SECNO=  33700.00            CWSEL=     702.17

STA=       57.      130.      240.      245.      285.      410.      457.      522.
  PER Q=       6.5      18.7       1.0      43.6      21.5       6.2       2.6
   AREA=     325.1     766.8      39.9     645.8     878.4     280.6     196.4
    VEL=       1.6       1.9       2.0       5.4       2.0       1.8       1.0
  DEPTH=       4.4       7.0       8.0      16.1       7.0       6.0       3.0
```

Output summary tables can be developed with interactive PC program SUMPO and simple cross-section, profile, and rating curve plots can be developed with PC program PLOT2 (Bonner, 1990a).

## Bridge & Culverts

When bridge crossings obstruct the overbank flow area, the transition of flow from overbank area to open channel area, and back to overbank flow, is modelled by the definition of cross-section effective flow area. The difference among the HEC-2 bridge and culvert options is in the method used to compute the bridge structure loss.

**Normal Bridge** provides a conveyance-based treatment of bridge crossings. Cross sections in the bridge are defined by adding bridge geometric data to eliminate the cross-sectional area blocked by the bridge. Conveyance calculations consider the added wetted perimeter and the obstructed area caused by the bridge.

**Special Bridge** provides hydraulic equations for low, pressure, road overflow, and flow combinations. Low-flow losses are based on impact loss due to bridge piers. Pressure flow uses a form of the orifice equation, and bridge over-flow is modelled with the weir equation. The bridge routine can handle combinations of pressure and weir, or low-flow and weir-flow.

**Special Culvert** provides the hydraulic equations from the Federal Highway Administration procedures (FHWA, 1985). All combinations of flow, considering both inlet and outlet control, can be computed for circular and box culverts. Multiple identical culverts are analyzed assuming flow is equally distributed among the culverts. The input for the culvert routine mimics that for the Special Bridge.

**Federal Highway Bridge Hydraulics** "WSPRO" (Sherman, et.al, 1986) have been added to HEC-2 in a test application. The present configuration is literally a "splice," with the input read, bridge loss calculations, and bridge output all performed within WSPRO code. The solution then returns to HEC-2 profile computations with the bridge result.

## Program Options

**Channel Modification** - One to three channel templates can be defined at a cross section. Input options support the computation of a base profile for existing conditions and additional profiles with cross sections modified based on the defined templates. With multiple templates, the modified channel can be a compound cut (e.g., low-flow and flood flow templates) or different template scales and locations can be evaluated in a single multiple profile computer run. Both channel reach length and Manning's "n" value can be changed for the modified channel.

**Floodway Routines** - Six methods are provided to define a floodway within the floodplain cross sections (Bonner, 1988). Several methods were developed to estimate the floodway limits based on FEMA criteria and a "target" increase in water surface elevation (FEMA, 1985). Special output tables are provided to support the reporting requirements for a FEMA flood insurance study.

**Split-flow Routine** - Lateral overflows can be modelled using a weir equation, normal depth, or a rating curve. Up to 100 overflow reaches can be defined. The flow lost at each overflow is computed, the channel flow is adjusted, and the computed profile is based on the remaining flow in the channel. All or a proportion of the lost flow can be returned at a downstream location. The routine can be used to model diversions, side-overflow weirs, levee overflow, or flow lost over a drainage divide (Montalvo, 1982).

**Ice Option** - A layer of floating ice can be defined by ice thickness, "n" value, and specific gravity. The cross-section conveyance calculations consider loss of flow area, added wetted perimeter, and computed composite "n" value. In addition to the hydraulic calculations, the potential for ice jams is determined using Pariset's ice stability function (HEC, 1990a, p 25).

**Storage-outflow Data** - The program computes the cumulative volume of water, under the water surface profile, in a river reach. Storage-outflow data can be provided, in HEC-1 Flood Hydrograph input format (HEC, 1990b), based on multiple water surface profiles. By computing profiles for a range of discharges, and specifying the cross-sections at the ends of the routing reach(s), storage-routing data can be provided in HEC-1 format, including record identifiers (Bonner, 1990b).

**Modified Cross-Section Input File** - This option provides an input data file, in basic X-Y coordinates (**GR** records), that incorporates cross-section changes made within HEC-2 with the application of section modification options. This option is useful when additional modeling, beyond the capabilities of the program options, is required. For example, you can obtain a data set created with the Channel Modification routine to perform analysis of a new bridge crossing or additional reach modifications.

## Next Generation HEC-2

While maintenance and minor modifications continue with HEC-2 and other programs, HEC started a new software development project last fiscal year. The NexGen (*Next Generation*) project is a five-year effort, under the Corps' R&D Program, to develop the replacement software operating and utilizing the full capabilities of the Engineering Workstation.

During last fiscal year, preliminary requirements documents were developed for catchment, river, reservoir, and flood-damage analysis. The river analysis system is envisioned to provide one-dimensional computations for steady and unsteady flow, plus sediment transport. These computational capabilities will

operate from a common geometric database for a river reach, or system. This will allow the modeler to move from steady to unsteady flow without having to reformulate the river-reach data. Also, graphics and output tables can be provided to support all 1-D modeling activities. The requirements document also proposed the development of a simple standard-step model as a prototype for the system.

During this fiscal year, the catchment model prototype is under development on a Unix workstation. This effort will address issues concerning graphical user interface, data flow and interaction, and general system architecture. The standard-step model prototype is under development in a DOS Windows environment. Using Windows allows us to design a user interface and develop the computational modules without dealing with multi-processing work-station issues.

While HEC-2 capabilities are the bases for the new model development, some of the basic building blocks are being developed "from scratch". The goal is to have computational modules that can support several purposes and allow user controlled interactive computations, when possible. The existing code for water surface profiles is too entangled with other program options. Once the basic standard-step program is functional, bridges and culverts will be added. Much of the bridge and culvert code will be salvaged from the present HEC-2. The intermediate product may be a Windows-based interactive steady flow model.

Input options will include existing HEC-2 data files, XYZ data from terrain models, and screen-menu entry. Easy graphical displays of input will include graphical editing of geometric data and some input parameters. When appropriate, computations can proceed one section at a time, or multiple profile batch processing like the present model. Graphical and tabular output will be provided.

Closely following the steady-flow model, an unsteady flow capability will be developed using the same basic geometric data. HEC is presently working with UNET, an unsteady-flow network model (Barkau, 1991). The program utilizes HEC-2 input to define the geometric data, making it easier for modelers familiar with HEC-2 to develop an unsteady flow model. Time-series data (hydrographs) are read from a random access datafile, HEC-DSS (HEC, 1990c). HEC-DSS is also used to store model results. Graphical and tabular displays of DSS data are provided with program DSPLAY.

The NexGen is an ambitious project for a small office to undertake. As with most software development, the delivery dates are in the future (*vapor-ware*) and the forecasts tend to be overly optimistic. However, we believe that it is time to build the models for the future. We hope that the combination of maintaining and modestly improving existing software, plus providing intermediate "prototype" programs, will keep the engineering community with sufficient computational capability to meet many of their hydrologic modeling needs.

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